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(54) Title: IMPROVED BUILT-UP ROOF SYSTEM

(57) Abstract: The present invention is an improved built-up roof system comprising an insulation layer, a coverboard layer, and a waterproofing membrane layer, wherein the coverboard layer comprises polyester foam.

IMPROVED BUILT-UP ROOF SYSTEM

The present invention relates to built up roof systems comprising an insulation layer, a coverboard layer, and a waterproofing membrane layer.

Low pitch roofs or built up roofs (BUR) are commonly constructed by installing an insulation layer on a roof deck, a coverboard layer over the insulation layer, followed by a waterproofing membrane layer. The waterproofing membrane layer can be composed of many different materials and is typically composed of asphalt and asphalt impregnated fiberglass ply sheet or modified bitumen. The coverboard layer most commonly is composed of fiberboard, perlite board or gypsum board. The coverboard layer protects the insulation layer from heat distortion, which can occur upon the application of hot asphalt, and reduces the risk of moisture entrapment between the waterproofing membrane layer and the insulation layer. However, current coverboard materials are not very moisture resistant, and moisture trapped between the waterproofing membrane layer and the coverboard layer within the BUR can cause roof delaminations and premature failures.

Other materials have been used in roofing applications as discussed in US-A-4,418,108 and US-A-6,067,770. US-A-4,418,108 discloses polyethylene terephthalate (PET) films used as a perforated sheet in a roofing panel. Additionally, US-A-6,067,770 relates to multi-layer polymer systems, including PET, used to prevent condensation in buildings. However, these materials do not have the needed high temperature resistance and/or have not been utilized in a BUR system.

Therefore, there remains a need for a BUR system with increased resistance to moisture, delamination and failures.

The present invention is an improved BUR system, wherein the coverboard layer comprises polyester foam sheet. The polyester foam sheet is very moisture resistant and can be directly applied to the insulation layer prior to the roofing process. This eliminates the separate step of installing the coverboard during roof construction.

In a BUR system comprising an insulation layer, a coverboard layer, e.g. fiber board, perlite board or gypsum board, and a waterproofing membrane layer, the present invention is an improvement, wherein the coverboard layer comprises a polyester foam instead of fiber board, perlite board or gypsum board. Preferably the polyester foam is a foam sheet. The polyester foam coverboard utilized in the present invention is lighter in weight and has much lower water absorption than currently used materials in BUR systems.

The insulation layer used in the BUR system of the present invention can be any insulation useful in roofing applications and is typically a foamed insulation material. Such insulation includes, but is not limited to, polyisocyanurate foams, extruded polystyrene foam insulation, expanded polystyrene foam insulation, extruded polypropylene foam, and phenolic foams. These foam insulations and their methods of manufacture are well known in the art.

The insulation layer may be any thickness in the built up roof application. Typically, the BUR contains sufficient insulation to meet local building codes. Preferably, the BUR achieves an R15 rating as determined according to ASTM C-518. As known in the art, this rating, or any desired rating, can be achieved by various thicknesses depending on the insulation material used.

The polyester foam generally has a thickness of 0.02 inches (0.5 millimeter (mm)) or more. Conceivably, there is no upper limit on how thick the polyester foam can be. Thinner foams are easier to handle, particularly if they can be stored and handled in roll form. Therefore, the polyester foam is preferably a foam sheet. Herein, a "polyester foam sheet" refers to a polyester foam having a thickness of 0.02 inches (0.5 mm) or more, more preferably 0.04 inches (1 mm) or more and 0.25 inches (6.35 mm) or less.

The polyester foam layer can be made from any polyester that has good heat and moisture resistance. For example, high-molecular weight chain esters obtained by reacting an aromatic dicarboxylic acid and a dihydric alcohol can be used. The aromatic dicarboxylic acid may be terephthalic acid, isophthalic acid, 2,6-naphthalenedicarboxylic acid, diphenyl ether dicarboxylic acid, diphenylsulfonedicarboxylic acid, and diphenoxydicarboxylic acid. The dihydric alcohol can be ethylene glycol, trimethylene glycol, tetramethylene glycol, neopentylene glycol, hexamethylene glycol, cyclohexanedimethylol, tricyclodecanedimethylol, 2,2- bis-(4-beta-hydroxyethoxyphenyl) propane, 4,4'-bis(beta-hydroxyethoxy)diphenylsulfone, diethylene glycol, and their respective esters. Polyethylene terephthalate (PET) and polybutylene terephthalate are preferred. The polyesters may be used singly or in any mixture thereof.

Methods of making polyester foam and foam sheet are well known in the art such as in US-A-5,340,846; US-A-5,000,991; US-A-5,362,763; US-A-5,422,381 and US-A-5,958,164.

In the BUR of the present invention, the polyester of the foam preferably has a crystallinity 20 to 35 percent (%). In other words the polyester will have 20% to 35% crystalline structure within an amorphous phase, wherein the amorphous phase makes up the balance. Increasing the crystallinity of a polyester foam increases its resistance to thermal deformation. A crystallinity of 20% or more is desirable to resist deformation during application of membrane materials, which can be at temperatures up to 500 degrees Fahrenheit (°F), or 260 degrees Celsius (°C) or more during application. Lower crystallinity foams are suitable for BURs that utilize membrane materials that can be applied at lower temperatures. In general, the polyester foam should have sufficient crystallinity so as to not deform during application of membrane materials. Polyester foams having a crystallinity above 35% tend to get brittle and fracture when walked on. While polyester foams having a crystallinity above 35% can be used in the present invention, they are not preferred.

A polyester foam's crystallinity is dependent upon the foam's heating history. In other words, the crystallinity varies by the type and temperature of the heating media and the contact conditions of the foam with the heating media. Typically, crystallization is accomplished by holding the polyester foam at a temperature between 300°F (149°C) and 380°F (193°C) for a duration of between 2 and 6 seconds. However, any foam that inhibits heat transfer during the initial cooling of the foam after formation will crystallize to some degree, since the foam passes within the above conditions. Foam sheet is desirable because its thickness allows for rapid heating during the crystallization process.

Any method of heating can be utilized to establish crystallinity. In one embodiment for foam sheet, a cylindrical sheet is heated by placing a mandrel heated with heat transfer oil inside the cylinder and allowing the sheet to proceed along the mandrel having a length as long as possible. Alternatively, a flat sheet or board can be placed between a pair of rollers heated with heat transfer oil and allowed to proceed while heating, wherein the diameters of the rollers is as large as possible.

Determine percent crystallinity from the crystallinity fraction (X_c) using to the following formula:

$$\text{Percent crystallinity} = 100\,(X_c) = 100\,(\Delta_{fus}H)/(\Delta_{fus}H^{o})$$

Wherein $\Delta_{fus}H$ is the heat of fusion of the polyester foam (as determined by calorimetry) and $\Delta_{fus}H^{o}$ is the heat of fusion for the fully crystalline polyester material. $\Delta_{fus}H^{o}$ is often

available in readily available reference tables. Alternatively, $\Delta_{fus}H^{o}$ can be determined using one of the methods described by H. G. Ferguson et al. (Thermochimica Acta 363 (2000) page 8 section 3.1.1.) and references cited therein.

The polyester foam typically has a density of 0.04 to 0.3 grams per cubic centimeter (g/cm^3). Decreasing a foam's density typically lowers the foam's cost and increases the foam's thermal insulating ability, both of which are desirable. Increasing a foam's density typically enhances the foam's compressive strength thereby enhancing the load that can be placed upon the foam without deforming the foam. High compressive strengths are desirable. Preferably, the polyester foam has a density of 0.06 g/cm^3 or more and 0.25 g/cm^3 or less.

The polyester foam is typically comprised of a closed cell foam with average cell size of from 0.0002 to 0.020 inches (0.005 to 0.5 mm). Cell sizes of 0.005 to 0.010 inches (0.1 to 0.25 mm) are typical for a foam of uniform thickness, composition, and appearance and can be produced using blowing agents and nucleators known in the art.

Polyester foam can also be made from recycled material as taught in WO 90/10667. Dried scrap PET is reacted with a polyfunctional carboxylic acid anhydride such as pyromellitic acid dianhydride and trimellitic acid anhydride, in amounts of 0.05% to 2.5% by weight of the PET, at a temperature between 250 and 300°C, to obtain a composition of modified PET with a higher viscosity. This material can then be foamed by methods known in the art.

The polyester foam can be adhered or laminated to the insulation layer prior to construction of the BUR system or during roof construction. In a preferred embodiment, the polyester foam is applied directly to or laminated to the insulation layer prior to roof construction. This eliminates the onsite installation of the coverboard separate from the insulation layer in the roofing construction process. Lamination of the polyester foam to the insulation layer can be achieved by any method and is dependent upon the material used for insulation, i.e. polyisocyanurate foams would not require any additional process or adhesive. Typical processes for adhesion include heat fusion, adhesives, and co-extrusion by extruder if needed. Desirably, laminations of the polyester foam and insulation foam are rollable, allowing for storage in roll form and application by unrolling onto a roof deck.

If the polyester foam is installed on site to the insulation layer during roof construction, the foam can be either adhered or mechanically attached. That is, an adhesive

can be used to adhere the foam sheet to the insulation, or mechanical means, such as screws, nails, etc. can be used to attach the foam to the insulation and the roof deck.

The polyester foam, i.e. coverboard layer, is covered by a waterproofing membrane layer which can be any material ("membrane material") which is moisture resistant and will meet the standards specified in ASTM E-108 for fire resistant materials. Typically, these materials are bitumen materials, including asphalt and coal tar type bitumen. The bitumen can be modified bitumen, which is bitumen blended with a polymer material such as styrene/butadiene/styrene block copolymers, atactic polypropylene polymers, and ethylene/styrene copolymers or "interpolymers". An accepted procedure for applying membrane materials to a polyester foam on a roof include alternately layering a bitumen material and a reinforcing material (such as glass fiber or glass fiber mat) to achieve 3-4 plies of the bitumen/reinforcing material. A final bitumen layer (flood coat) is applied over the 3-4 plies and a coating of pea gravel it typically applied to the final bitumen layer. Membrane materials can be applied as pre-manufactured rolls that contain bitumen (or modified bitumen) and reinforcing materials by rolling the pre-manufactured materials onto a polyester foam and sealing seams with bitumen. A skilled artisan can identify many different methods of applying membrane materials over the polyester foam to achieve the present invention.

The following examples are provided to illustrate the present invention. The examples are not intended to limit the scope of the present invention and they should not be so interpreted. Amounts are in weight parts or weight percentages unless otherwise indicated.

<u>Example 1</u>

PET foam sheet (2.5 mm thick, density of 0.13 g/cm^3 as determined according to ASTM-D1622, and 0.6 m wide by 1.2 m long) is laminated to STYROFOAM™ (trademark of The Dow Chemical Company) brand extruded polystyrene foam using Ashland Chemicals adhesive Isomelt PUR™ 200. Two laminated sheets are then butted together to make a 1.2 meter square block. Hot asphalt is applied to the PET foam surface of the laminated material at a temperature of 220 °C and at a rate of 2 kilograms per square meter (kg/m^2). A layer of asphalt impregnated fiberglass ply sheet is then pressed into the molten asphalt and the composite is cooled.

After cooling to atmospheric temperature, there is no evidence of any physical distortion of the insulation foam. Cutting the board through sections of the composite shows no evidence of melting or color change in the polystyrene foam.

The above test is repeated with isocyanurate foam insulation and expandable polystyrene foam insulation, with similar results.

Example 2.

Prepare two laminated composite foam structures comprising a PET foam sheet, an isocyanurate foam, and a facer according to the procedure in Example 4 of United States Patent number 5,308,883 by including a facer sheet on one surface of the structure and a PET foam sheet on the other surface (see Example 3 of US 5,308,883 for a description of how to prepare structures with two facers. Replace one of the facers with a PET foam sheet). The PET foam sheet is 1.2 m wide, 2.4 m long, 1 mm thick, 25% crystalline, and has a 0.23 g/cm^3 density according to ASTM-D1622. The isocyanurate foam is 51 mm thick. The laminated composite foam structure comprises a PET foam affixed to a polyisocyanurate foam. The polyisocyanurate foam has a facer on a surface opposite the PET foam.

Butt the two laminated composite foam structures together to form a 2.4 m square block and fasten the structures to a wooden test deck using standard BUR fasteners (*e.g.*, Olympic Fastener HD#14, 12 fasteners per structure) with the facer against the wood structure and the PET foam exposed. Hot mop asphalt (220 °C) onto the PET foam at a rate of 2 kg/m^2 until the PET foam is covered with asphalt. Apply a fiberglass ply sheet that meets ASTM D-2178 Type IV and Type VI specifications. Apply two more alternating layers of asphalt and fiberglass ply sheet followed by a final coat (flood coat) of asphalt. Apply pea gravel to the still soft flood coat. There is no apparent physical distortion of the laminated composite foam structure even after application of the asphalt and fiberglass plies.

Example 2 illustrates a BUR structure comprising a laminated composite structure of PET foam and insulating foam (isocyanurate foam) that is within the scope of the present invention.

CLAIMS:

1. In a built-up roof system comprising an insulation layer, a coverboard layer, and waterproofing membrane layer, an improvement wherein the coverboard layer comprises a polyester foam.

2. The built up roof system of Claim 1, wherein the polyester foam is a polyester foam sheet.

3. The built-up roof system of Claim 1, wherein the insulation comprises a polyisocyanurate foam, extruded polystyrene foam, expanded polystyrene foam, extruded polypropylene foam, phenolic foam or expanded polypropylene foam.

4. The built-up roof system of Claim 1, wherein the coverboard layer is adhered or laminated to the insulation layer prior to roof construction.

5. The built-up roof system of Claim 4, wherein the coverboard layer and insulation layer are laminated together prior to roof construction and is in the form of a roll which can be applied during roof construction.

6. The built-up roof system of Claim 1, wherein the polyester is a high-molecular weight chain ester obtained by reacting an aromatic dicarboxylic acid selected from terephthalic acid, isophthalic acid, 2,6-naphthalenedicarboxylic acid, diphenyl ether dicarboxylic acid, diphenylsulfonedicarboxylic acid or diphenoxydicarboxylic acid and a dihydric alcohol selected from ethylene glycol, trimethylene glycol, tetramethylene glycol, neopentylene glycol, hexamethylene glycol, cyclohexanedimethylol, tricyclodecanedimethylol, 2,2- bis-(4-beta-hydroxyethoxyphenyl) propane, 4,4'-bis(beta-hydroxyethoxy)diphenylsulfone, diethylene glycol, or their respective esters.

7. The built-up roof system of Claim 7, wherein the polyester is polyethylene terephthalate or polybutylene terephthalate.

8. The built-up roof system of Claim 1, wherein the polyester foam sheet has a foam density of from 0.04 to 0.3 g/cm^3.

9. The built-up roof system of Claim 1, wherein the waterproofing membrane layer comprises applications of asphalt and glass ply sheet.

10. The built-up roof system of Claim 1, wherein the waterproofing membrane layer comprises modified bitumen sheet.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/13848

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E04D3/35

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E04D E04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	US 3 029 172 A (GLASS JOHN Y) 10 April 1962 (1962-04-10) the whole document	1,2,4,9, 10 3,6-8 5
Y	US 4 351 873 A (DAVIS DUANE A) 28 September 1982 (1982-09-28) column 2, line 43-52; figure 1	3
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Y	US 5 422 381 A (AL GHATTA HUSSAIN A K ET AL) 6 June 1995 (1995-06-06) cited in the application column 2, line 17-29; claim 9	7,8

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
5 July 2002	22/07/2002

Name and mailing address of the ISA	Authorized officer
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Form PCT/ISA/210 (second sheet) (July 1992)

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 958 164 A (ISHIWATARI SUSUMU ET AL) 28 September 1999 (1999-09-28) cited in the application column 1, line 7-12 column 9, line 28-31 column 10, line 52-55	8
A	US 3 111 787 A (CHAMBERLAIN MERLE D) 26 November 1963 (1963-11-26) the whole document	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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